Simulation-Based Team Training Improves Team Performance among Pediatric Intensive Care Unit Staff

Nora Colman[1,2,3] Janet Figueroa[2] Courtney McCracken[2,3] Kiran Hebbar[1,2,3]

[1] Division of Pediatric Critical Care, Emory University School of Medicine, Atlanta, Georgia, United States
[2] Department of Pediatrics, Emory University School of Medicine, Atlanta, Georgia, United States
[3] Division of Pediatric Critical Care, Children's Healthcare of Atlanta, Atlanta, Georgia, United States

Address for correspondence Nora Colman, MD, Division of Critical Care Medicine, 1405 Clifton Road NE, Atlanta GA 30329, United States (e-mail: Nora.Colman@choa.org).

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Abstract

Simulation training fosters collaborative learning and improves communication among interdisciplinary teams. In this prospective observational cohort study, we evaluated the impact of interdisciplinary simulation-based team training (SBTT) on immediate learning of team performance behaviors. In a 3-month period, 30 simulation sessions were conducted and 165 staff members, including physicians, nurses, and respiratory therapists, were trained. Regression analysis showed a statistically significant improvement in team performance ($p < 0.0001$). Study results demonstrate that SBTT is effective in immediate acquisition of optimal team performance behaviors by multidisciplinary pediatric intensive care unit staff, including physicians with higher level subspecialty training in the simulation environment.

Keywords
► simulation
► team performance
► team training

Introduction

Nearly 6,000 children in the United States require cardiopulmonary resuscitation each year, with 2 to 6% of those events occurring in the pediatric intensive care units (PICUs).[1,2] Although not captured in the literature, anecdotally decompensating medical crises (DMCs) occur with much higher frequency in the pediatric ICU populations compared with cardiac arrest events. We use DMCs to describe precardiac arrest events which are characterized by respiratory and hemodynamic instability lasting minutes to hours secondary to the patient's underlying illness. These conditions require complex medical management and are dependent on high-functioning teams that are able to achieve optimal team performance.

Emerging literature suggests that the quality of teamwork and optimal teamwork behaviors impacts safety culture, error rates, process efficiencies, and patient outcomes.[3,4] ICU teams are prone to errors as management of complex clinical situations requires dynamic and complex interactions of providers. Literature on teamwork seeks to understand how the evaluation of teamwork in an ICU environment can provide insight into what aspects of teamwork are most impactful and how these behaviors can be translated into clinical practice.[4]

The effectiveness of team performance is defined by the quality of teamwork as it relates to predetermined goals.[4] Despite the importance of having coordinated teams to deliver safe care, most healthcare professionals never receive formal training in teamwork behaviors and communication skills.[5–8] Pediatric trainees lack a significant clinical context gained from caring for patients and their roles may not account for cultural norms of individual units.[9] In our unit, trainees play a passive role in the management of emergency events and do not function as key members of our native team.[10]

The objectives of this study were to measure immediate acquisition of optimal team performance behaviors during interdisciplinary simulation-based team training and

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perform a qualitative analysis of common trends in teamwork performance observed. We hypothesized that learners would overrate their team's performance and that facilitator scores would not improve as a single training session may not be adequate to gain skill acquisition.

Methods

Setting/Simulation Type

A simulation-based team training workshop was implemented in the PICU at Children's Healthcare of Atlanta (CHOA) at Egleston (ECH) between July 2016 and September 2016. Critical care nursing staff, respiratory therapists, PICU attendings, and PICU fellows participated in simulation training. ECH is a freestanding 272 bed pediatric teaching hospital and referral center with a 36-bed PICU. The project was determined to be nonhuman subjects research by CHOA Institutional Review Board.

The simulation laboratory at ECH is an in-situ laboratory built into the last room in the PICU. The room is used for patient care and when volumes allow it is used for simulation training. It consists of a control station behind one-way glass, ceiling-mounted microphone, two ceiling-mounted cameras, a mounted Laerdal monitor with all cables, and connectors running through the walls to the control station. Labs and radiographs are projected on to a separate mounted TV located in the room. The laboratory utilizes a high-fidelity human infant (6–8 months) mannequin (2014 SimBaby; Laerdal Medical Stavanger, Norway).

Participant Orientation

Each simulation training included a scripted 30-minute briefing, which included an introduction to simulation, objectives for the training session, clarification of participant and facilitator roles, logistics and timing of the session, and mannequin introduction. Learners were able to examine the mannequin during this time and were informed that temperature, color, and capillary refill time would be described by the facilitator. Participants were also oriented to the location and availability of nursing equipment including syringe pumps, computers, medications, and respiratory equipment, including noninvasive respiratory support and intubation supplies.

Simulation Event

During the 3-month training period, 30 team training workshops were conducted. Each scenario was pre-programmed based on a detailed script. Scenarios were not videotaped. Detailed scripts for mannequin settings, trained embedded participants, and facilitator triggers were used during each workshop to standardize the training and minimize variation in participant experience.[11] Time-sensitive triggers were programmed and embedded into the script to prompt progression of each clinical scenario (►**Table 1**).

Each workshop consisted of a team of five to six learners, three to four PICU nurses, one respiratory therapist, and one critical care physician (attending or fellow). All staff were required to participate as part of their mandatory annual clinical competencies.

Each workshop was 3 hours long and consisted of three scenarios: septic shock, refractory bronchospasm, and pulmonary hypertensive crisis with cardiac arrest. Specific teamwork objectives were preidentified for each scenario based on literature describing teamwork behaviors and skills felt to be deficient in our unit yet most clinically relevant.[4,8,12] Specific skills included leader identification, use of closed loop and directed communication, role assignment and clarity, shared mental model, and global assessment.

Scenarios were based on real-life cases frequently encountered in our PICU. Each scenario was progressive in terms of complexity, severity of illness, and patient acuity requiring higher levels of team functioning to manage the patient. Primary objectives are noted in ►**Table 1**.

Adjuncts provided to learners for included X-ray images which were displayed on a mounted computer monitor, and an epic (electronic medical record) chart which included providers notes and laboratory results.

Three members from the simulation team conducted each workshop: two facilitators and one simulation technician. The same two facilitators, one pediatric intensivist (KBH, senior author), and one simulation coordinator with previous ICU experience were present at every workshop. Both facilitators with extensive experience in delivering simulation underwent structured training in debriefing healthcare teams in a simulated environment. Additionally, they were trained on crisis resource management principles and theory-based debriefing. These same two facilitators were also embedded participants, acting as a distracting physician or a concerned parent in the scenarios, never simultaneously. Facilitators were provided with a detailed script describing their embedded role as well as triggers for when to enter the scenario. In-depth understanding of the simulation program and objective enhanced compliance with roles and aided in standardizing the experience for all learner groups. The simulation technician operated the mannequin and also made scripted phone calls to the learners with radiology readings and provided report from the emergency room. Scenarios were rehearsed once, refined, and then practiced a second time on members of the leadership team.

Instruction Design

Each scenario was conducted only once, lasted 20 minutes and was followed by an immediate debrief lasting 35 to 45 minutes. The same three scenarios were conducted in each training session and presented to the teams in the same order with the same laboratories, radiographs, and echocardiography reports. Physicians and respiratory therapists maintained their roles for all three scenarios, while the nurses rotated between being a primary nurse and resource nurse. Resource nurse roles included a recorder, runner, compressor, or medication nurse. Assignment to these roles was based on designation by the team leader during the scenario.

Debriefings

Two facilitators followed a structured debriefing script which included a short introduction to the content of the debrief. The script provided facilitators with learning objectives for

Table 1 Simulation-based team training scenario overview and team performance learning objectives

Brief scenario description	Brief description of scenario progression and required interventions	Teamwork objectives
Scenario 1 (Septic Shock): Patient is a 9-month-old infant with uncompensated septic shock that clinically deteriorates despite all interventions. This case ends with impending arrest	Phase I: 8–9 **minutes** Team obtains history, performs physical exam, recognizes shock and respiratory failure. Team administers fluid resuscitation, corrects hypoglycemia, orders laboratories and antibiotics.	Team leader identifies themselves, assigns roles. Team uses directed communication and shares mental model
	Phase II: 6–8 minutes Patient develops progressive respiratory failure, hemodynamic instability unresponsive to fluids. Patient requires bag/mask ventilation, fluid resuscitation, inotropic support. Team prepares for intubation	Team leader avoids fixation errors, delegates tasks, uses direct and closed loop communication
	Phase II: 3–5 minutes Patient decompensates with impending arrest secondary to hypoxia, bradycardia, and hypotension. Team prepares to perform CPR	Team leader assigns roles for impending arrest (compressor, airway management, drug nurse, recorder) and directs location of team members around the bedside
Scenario 2 (Bronchospasm): Patient is a 5-month-old infant with respiratory failure secondary to bronchospasm who cannot be ventilated throughout the case. Ventilation does not improve with medical interventions	Phase I: 4 minutes Team assess patient, obtains history, recognizes hypercarbia and difficulty with ventilation, recognizes difficult airway, obtains imaging, and/or laboratories	Team utilizes situational awareness, leader obtains information, talks to team outload, shares mental model
	Phase II: 8–10 minutes Worsening hypercarbia. Team uses DOPE mnemonic to assess ventilation failure, recognizes bronchospasm, orders medication to manage bronchospasm	Team leader actively obtains information about the patient, communicates assessment with team members, predicts that patient may continue to decompensate, anticipates needs for further interventions. Team members share ideas with team leader. Team maintains flattened hierarchy
	Phase III: 7–10 minutes Continued bronchospasm despite medical intervention. Team considers other reasons for ventilation failure, considers ECMO	Team leader recognizes failure of medical therapy, shares mental model with team, communicates findings, anticipates further interventions
Scenario 3 (pulmonary hypertensive crisis): Patient is a 7-month-old infant with chronic lung disease that presents with a pulmonary hypertensive crisis. Patient decompensates, progressing into cardiorespiratory arrest and requires CPR	Phase I: 8–9 minutes Team assesses patient, obtains history, recognizes respiratory failure, provides fluids, replaces electrolytes, orders imaging and/or laboratories	Team leader identifies themselves, assigns roles, directs positioning of team members around the bedside. Team members use of SBAR to orient new team members. Team uses closed loop communication
	Phase II: 5–9 minutes Progression to respiratory arrest. Team prepares to intubate patient, performs bag/mask ventilation, obtains additional IV access	Leader role clarified, leader formulates lists of tasks, uses closed loop communication, shares mental model with team, team members speak up and share mental model with team leader
	Phase II: 6–9 minutes Patient develops hypoxic respiratory arrest requiring CPR. Team calls code blue, starts chest compressions, follows PALS algorithm for bradycardic arrest	Team leader anticipates any team limitations, reassess and evaluates progress of resuscitation, avoids performing tasks themselves. Team leader identifies roles, directs location of team members around the bedside. Team members utilize directed and closed loop communication, team maintains flattened hierarchy. Team avoids target fixation

Abbreviations: CPR, cardiopulmonary resuscitation; DOPE, displacement, obstruction, pneumothorax, equipment; ECMO, extracorporeal membrane oxygenation; PALS, pediatric advanced life support; SBAR, situation, background, assessment, recommendation.

each scenario. Debriefing consisted of three phases: (1) reactions phase (5–10 minutes) where participants were asked to share their initial feelings following completion of the scenario, (2) descriptive phase (5 minutes) where the primary nurse and physician were asked to give a one-line summary of what had occurred clinically during the scenario, and (3) the analysis phase (15–20 minutes) where facilitators aimed to assess the learners frame and close any performance gaps. As time was not a barrier, debriefings allowed for learner-focused facilitation which allowed facilitators to adapt the discussion to the needs of the learner. Directive feedback and facilitator focused discussion ensured consistency in the key objectives discussed. Content of the debriefings was focused on teamwork behaviors, team leader identification, role assignment, direct and closed loop communication, situational awareness, shared mental model, and global assessment (►**Table 1**). Little focus was placed on medical management and decision making.

Clinical Training Scale Tool and Data collected in Simulation

Data on team performance was collected during simulation training using the Clinical Training Scale Tool (CTS).[13] This tool was validated against known standards of teamwork and was found to be reliable among raters using Pearson's correlation coefficient and Kappa coefficient to compute inter-rater reliability. This tool is intended to provide assessment of teamwork skills by a group of providers and require minimal training. The tool delineates five conceptual categories: communication, situational awareness, decision making, role responsibility, and patient friendliness. The tool uses a 11-point Likert scale (0 being unacceptable 10 being perfect) allowing for detection of less than extreme differences. Scores are clustered in four groupings with individual concepts linked to an anchoring descriptor. Simulation learners completed the tool and evaluated the team's performance following each scenario debrief. Following each scenario, the facilitators took 5 minutes to huddle and discuss performance gaps and common pitfall observed during the scenario. During the debrief, facilitators also took notes on common issues discussed. While the simulation technician set up for the next scenario, facilitators utilized the assessment tool to score the groups team performance following each scenario debrief. Facilitator notes on each scenario were summarized in an excel spreadsheet at the completion of the 30-session program. Gaps in native teamwork performance were categorized by failures in communication, role clarity/role assignment, shared cognition, and decision making.

Statistical Methods

Descriptive statistics were calculated for all variables of interest and include means and standard deviations, medians and ranges or counts and percentages, as appropriate. Generalized estimating equations (GEE) were used to determine changes in teamwork performance between scenarios 1, 2, and 3. Least-squares means (LS-means) from the GEE models were estimated for each scenario and compared using a Tukey-Kramer multiple comparison adjustment. Linear trends in scores from scenario 1 to scenario 3 were tested using linear orthogonal contrasts in the LSMESTIMATE statement in SAS (SAS Institute; Cary, North Carolina, United States). Inter-rater reliability between simulation coordinators was assessed using ICC (intraclass correlation coefficient) and computed using the %INTRACC macro with associated 95% confidence intervals. For interpretation purposes, ICC scores of 0.0 to 0.2 indicates slight agreement, 0.21 to 0.40 indicates fair agreement, 0.41 to 0.60 indicates moderate agreement, 0.61 to 0.80 indicates substantial agreement, and 0.81 to 1.0 indicates almost perfect or perfect agreement. Analyses were conducted using SAS v. 9.4 (Cary, North Carolina, United States) and statistical significance was assessed at the 0.05 level unless otherwise noted.

Results

Simulation Workshops

One hundred and sixty-five PICU staff members participated in a 3-hour SBTT workshop (►**Table 2**). A total of 492 evaluations were completed by learners during simulation training (►**Fig. 1**). Paired *t*-testing showed a statistically significant improvement in teamwork performance as each scenario progressed from scenario 1 to 2, and from scenario 2 to 3 ($p < 0.0001$) when rated by learners (►**Table 3**). Box plots demonstrated trend in scores across scenarios for the individual teamwork skills (►**Fig. 2**) with a significant improvement between each scenario.

Table 2 Participant demographics

Characteristics of study participant	*n* (%) of cohort ($n = 165$)[a]
Discipline	
Nurse	110 (66%)
Respiratory therapist	30 (18%)
PICU attending	9 (5%)
PICU fellow	16 (9%)
Gender	
Female	85.5%
Male	14.5%
Length of time practicing discipline	
Less than 6 months	9%
More than 1 year	37%
More than 5 years	21%
More than 10 years	32%
Participation in simulation	
Never	18%
Once	31%
More than 5 times	32%
More than 10 times	17%

Abbreviation: PICU, pediatric intensive care unit.
[a]Because of rounding, percentages may not total 100.

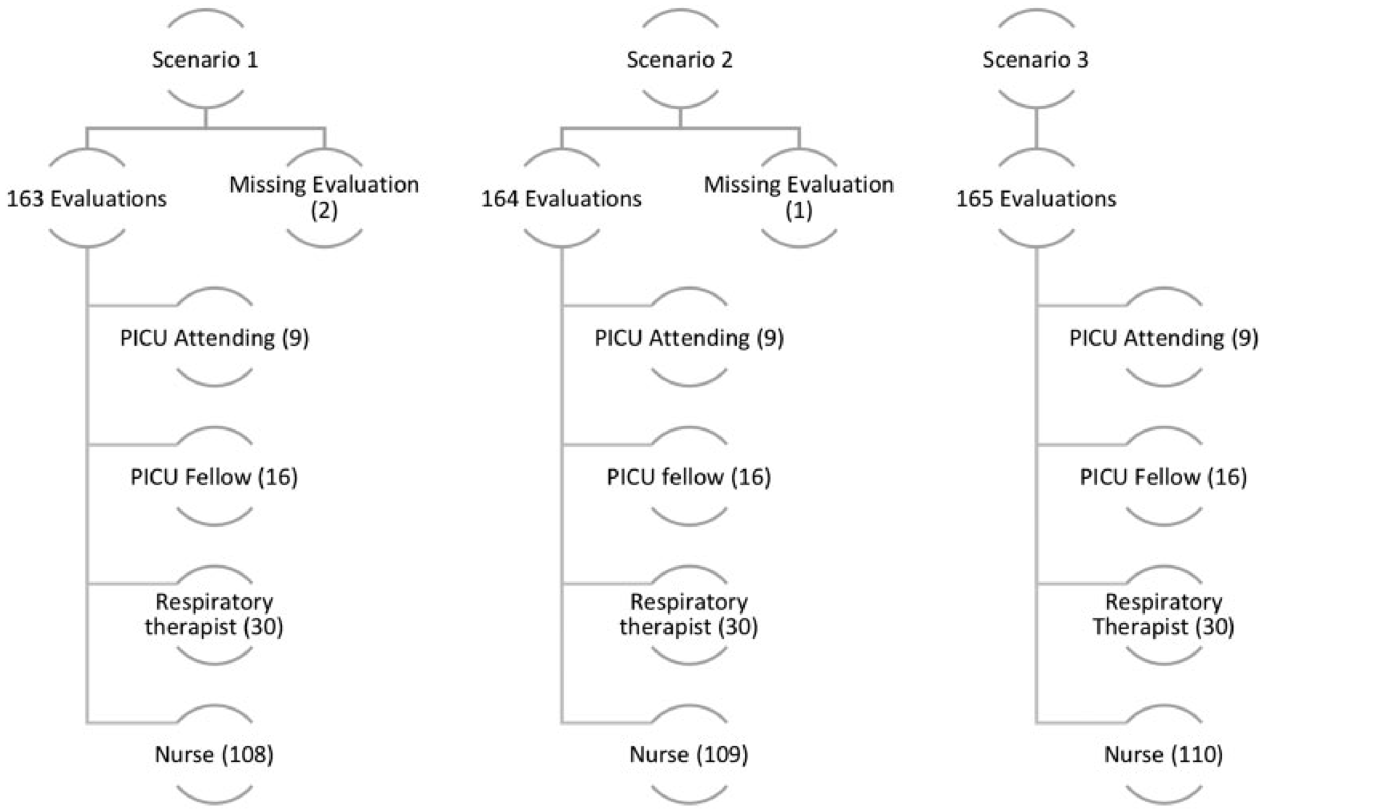

Fig. 1 Flow diagram of data collection. PICU, pediatric intensive care unit.

Table 3 Mean team performance scores when rated by participants

Questions LS means[a] (SE)	Scenario 1 (severe sepsis) $n = 163$	Scenario 2 (bronchospasm) $n = 164$	Scenario 3 (pulmonary hypertension) $n = 165$	p-Value[b]
How would you rate teamwork during this emergency?	6.4 (0.17)[a]	7.1 (0.14)[b]	8.5 (0.11)[c]	<0.0001
Overall communication	5.8 (0.17)[a]	7.0 (0.15)[b]	8.3 (0.11)[c]	<0.0001
Orient new members to SBAR	4.7 (0.19)[a]	6.0 (0.21)[b]	8.1 (0.14)[c]	<0.0001
Transparent thinking	5.6 (0.19)[a]	6.4 (0.15)[b]	8.3 (0.11)[c]	<0.0001
Directed Communication	5.9 (0.18)[a]	7.3 (0.15)[b]	8.4 (0.12)[c]	<0.0001
Closed loop communication	5.3 (0.16)[a]	7.1 (0.15)[b]	8.2 (0.13)[c]	<0.0001
Situational awareness	6.0 (0.18)[a]	6.8 (0.17)[b]	8.3 (0.13)[c]	<0.0001
Resource utilization	6.5 (0.18)[a]	7.2(0.15)[b]	8.3 (0.12)[c]	<0.0001
Overall decision making	6.6 (0.15)[a]	7.1 (0.15)[b]	8.3 (0.11)[c]	<0.0001
Prioritize	6.7 (0.17)[a]	7.1 (0.13)[a]	8.3 (0.14)[b]	<0.0001
Overall decision-making responsibility rating (leader/helper)	6.6(0.18)[a]	7.3 (0.13)[b]	8.4 (0.13)[c]	<0.0001
Role clarity	6.1 (0.19)[a]	7.5 (0.20)[b]	8.5 (0.15)[c]	<0.0001
Perform as a leader/helper	6.4 (0.15)[a]	7.3 (0.13)[b]	8.3 (0.12)[c]	<0.0001
Patient friendly	6.7 (0.19)[a]	7.0 (0.17)[a]	8.4 (0.14)[b]	<0.0001

[a]Least squares (LS) means from PROC GENMOD model for clustered (simulations/events) data.
[b]p-Value: Linear trend test using LSMESTIMATE statement in PROC GENMOD (orthogonal contrasts).
[c]LS means with the same letter are not statistically different.
Note: LS means with the same letter are not significantly different from one another. LS means with different letters are significant at the 0.05 level after Tukey adjustment for all pair-wise comparisons.

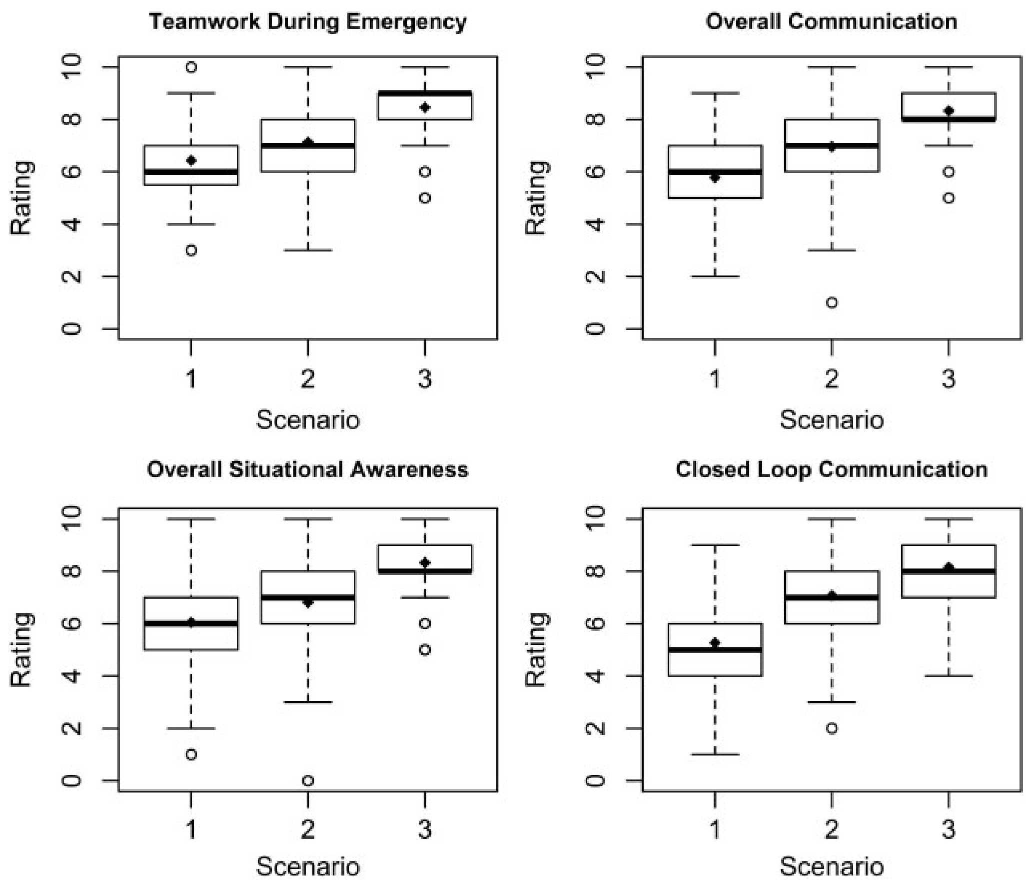

Fig. 2 Trends in scores of clinically significant teamwork skills.

Teamwork scores when rated by simulation facilitators also demonstrated a significant improvement in the overall teamwork rating score as well as each individual teamwork skill from scenario 1 and 2 and from scenario 2 to scenario 3 (►**Table 4**). Overall teamwork rating is an individual component score and rated as a single item as part of the CTS tool. Overall team rating, closed loop communication, directed communication, role clarity, demonstrated highest reliability an ICC score of > 0.8. Common trends and gaps in teamwork performance identified during training are detailed in ►**Table 5**.

Discussion

This study demonstrates effectiveness of SBTT on teaching teamwork skills, to native teams of key frontline staff including those with high level of subspecialty training such as fellows and attendings. Acquisition of improved team performance behaviors was immediate as learners were able to apply these concepts to nonalgorithmic management of DMCs as well as cardiac arrest events in the simulation environment. Common gaps in team performance behaviors were also easily identified during simulation-based training.

Literature from the surgical and emergency room arena has demonstrated the effectiveness of simulation-based training on team performance and teamwork attitudes.[14–17] Fewer studies have been performed in the pediatric ICU setting. In a recent study by Gilfoyle et al, simulation effectively improved adherence to PALS guidelines and improved teamwork performance among interdisciplinary teams.[18] This study excluded subspecialty trainees with more than 6 months of intensive care experience and did not focus on pediatric critical care bedside staff. Focus was on resuscitation teams, with more experienced personnel, designated in those hospitals. Unlike our study, teams were given a 3-hour interactive lecture and group discussion of video examples of resuscitation team performance. It can be difficult to determine which aspect of educational offering lecture, group discussion, or simulation contributed to change in performance and to what degree. Like many simulation studies, the main outcome measure was technical skills and the teams' adherence to PALS guidelines when led by resident trainees (PGY 3 or less). A portion, not all, of the debriefing time was dedicated to discussing teamwork skills.

In contrast, our study evaluated the performance of teams led by fellows and attendings, with the sole focus of teaching teamwork skills. Two of the three scenarios were characterized by a DMC, which occur with much greater frequency in our ICU than cardiopulmonary arrest. We suspect this to be the case in other PICUs as well. We believe that because DMCs are not managed based on algorithmic guidelines, resuscitation of these patients requires a higher level of team performance and critical thinking. Teams may have chosen different approaches to address medical management, such as severe

Table 4 Mean team performance scores when rated by simulation experts

Questions LS means[a] (SE)	Scenario 1 (severe sepsis) $n = 23$	Scenario 2 (bronchospasm) $n = 22$	Scenario 3 (pulmonary hypertension) $n = 22$	p-Value[b]
How would you rate teamwork during this emergency?	4.8 (0.20)[a]	6.0 (0.22)[b]	7.1 (0.24)[c]	<0.0001
Overall communication	4.2 (0.17)[a]	5.8 (0.26)[b]	6.9 (0.31)[c]	<0.0001
Orient new members to SBAR	4.8 (0.26)[a]	5.8 (0.30)[b]	7.0 (0.42)[c]	<0.0001
Transparent thinking	5.0 (0.34)[a]	5.5 (0.33)[a]	7.4 (0.25)[b]	<0.0001
Directed communication	4.4 (0.28)[a]	6.2 (0.25)[b]	7.2 (0.29)[c]	<0.0001
Closed loop communication	3.3 (0.14)[a]	5.8 (0.23)[b]	6.7 (0.31)[c]	<0.0001
Situational awareness	5.7 (0.25)[a]	6.0 (0.32)[a]	7.5 (0.23)[b]	<0.0001
Resource utilization	5.3 (0.26)[a]	5.8 (0.31)[a]	7.4 (0.19)[b]	<0.0001
Overall decision making	6.5 (0.24)[a]	6.4 (0.19)[a]	7.7 (0.19)[b]	<0.0001
Prioritize	5.9 (0.33)[a]	6.2 (0.19)[a]	7.5 (0.23)[b]	<0.0001
Overall decision-making responsibility rating (leader/helper)	6.5 (0.29)[a]	6.5 (0.22)[a]	7.6 (0.20)[b]	0.0003
Role clarity	4.1 (0.16)[a]	5.8 (0.14)[b]	7.0 (0.30)[c]	<0.0001
Perform as a leader/helper	6.1 (0.20)[a]	6.5 (0.27)[a]	7.4 (0.16)[b]	<0.0001

[a]Least squares (LS) means from PROC GENMOD model for clustered (simulations/events) data.
[b]p-Value—Linear trend test (across Scenario 1, 2,3) using LSMESTIMATE statement in PROC GENMOD (orthogonal contrasts).
[c]LS means with the same letter are not statistically significantly.
Note: LS means with different letters are significant at the 0.05 level after Tukey adjustment for all pairwise comparisons.

bronchospasm, but such medical decision making was not discussed in the debrief unless it was incorrect.

Unique to our dataset, learners completed self-assessments of the team's performance following each simulated scenario. Improvement in scores across all three scenarios suggests that learners were able to self-reflect on the teams' performance, understand the teamwork concepts, and apply what they learned in the subsequent scenario.

Facilitator evaluations of the learner's teamwork indicated "poor" or "average" performance in the first scenario with significant improvement to a mean rating of "good" in the final scenario. Surprisingly, the improvement in facilitator scores parallels the scores reported by the learners despite our perceived difficulty to effectively apply team training concepts in such a short period of time.

The SBTT platform provided insight into our clinical practice and performance of our native PICU team. It offered an opportunity to learn how the perspectives of each discipline impacted interdisciplinary communication and teamwork. We observed several common trends in teamwork behaviors in the areas of communication, role assignment, situational awareness, and decision making throughout training (►**Table 5**). This information on native team functioning can be used to evaluate and improve processes or develop future trainings with potential to impact patient outcomes. For example, poor communication around medication administration identified a latent safety threat and highlighted a behavioral gap with great potential to lead to a medication dosing error.

In a critical care setting where work flow and patient care are dynamic, team members must be aware of their environment, have a shared understanding of the situation, effectively communicate, prioritize tasks, and have a positive attitude to provide optimal patient care.[7,8] Simulation helps foster culture change with frontline staff as they are able to see with their own eyes, through experiential learning, the benefit, problems, and application of teamwork concepts in clinical practice. Reflecting with members of your actual care team helps foster a deeper understanding of each provider's role. Changing practice through anecdotal reference is difficult to do, particularly with more experienced providers.

Participation of faculty physicians was essential to the success of this program. Unlike resident trainees, most of our attendings have had little to no formal training in teamwork. As a learner, the attending physicians participated with an open mind and willingness to self-reflect on their own performance and behaviors which were highly valued by the bedside staff. Dedicating 3 hours for participation by physicians took a great deal of commitment on their part but echoed that this activity was worthwhile and valuable to the ICU and its staff.

As a single center, it is unclear if the results are generalizable. A large time commitment is required from staff and physicians, and many resources are required to develop, set up, and implement such a high-fidelity simulation. SBTT took place in in-situ PICU laboratory which provided a familiar space for our participants. Leadership support was essential to the success of this program and highlighted the divisions dedication to foster a culture that values teamwork.

Table 5 Trends in native team performance observed during simulation-based team training

Teamwork category	Issue identified
Communication	• Closed loop communication was used infrequently, most notable during task assignment and medication administration
	• Medication dosing was verified by nurse as drug was being administered to the patient
	• Nurse giving drug closed the communication loop with the recorder and not physician
	• Nurse drawing medications did not read back and verify drug dose when given a verbal order by physician
	• Team lead asked, "can someone do ....?" Instead of using direct communication leading to poor resource utilization
	• Lack of directed communication lead to multiple people doing the same task or the task not getting completed at all
	• Silos of conversation left the physician team lead unaware of what team was thinking
	• Drug nurse assumed that team leader knew a drug was administered to the patient based on perceived eye contact
Role clarity/role assignment	• Roles were not always assigned by the physician
	• Nurses viewed the recorder is least important role
	• Recorder did not always know what time intervals to keep during a code and failed to clarify their role with the physician
	• Nurses frequently swapped in and out of their role as recorder, drug nurse, compressor or runner during a single event
	• Fellows attempted to simultaneously be the team leader and do procedures (such as manage airway) at the same time often missing essential changes in patient condition
	• Poor positioning of team members resulted in the recorder standing in the back of the room far from the team leader
Situational awareness/global assessment	• Bedside nurse did not always receive sign out about the patient from the physician
	• Physician did not address crowd control and was unaware of how extra people limited access to the patient
	• Team leader lost global assessment of patient condition while attempting to perform procedures (such as intubation)
	• Nurses and respiratory therapists were task oriented, often losing a global assessment of the patient and change in clinical condition
	• Staff did not always share with the physician what they were thinking
	• Physician did not often share what they were thinking with their team
	• Nurses were not able to anticipate the needs of the patient if physician did not share what they were thinking
	• Respiratory therapists answered phone calls while providing bag/mask ventilation to patient
Decision making	• Physicians gave multiple orders to nurses and respiratory therapists at the same time without providing them with a chance to read back and verify orders
	• When physicians gave multiple orders, they did not prioritize what they wanted first sometimes resulting in delay in availability of drugs or equipment

This study has several limitations. Improvement in aggregate and composite team performance scores when rated by learners may reflect inherent investment bias. Additionally, team performance was not measured in an actual patient care setting, limiting these findings to the simulation environment. As results were based on one simulated session, we cannot make any inferences on how long these skills and behaviors learned will last beyond training.

Further research is needed to determine whether these skills learned during simulation training are applied to real emergency events, dosing of simulation to maintain proficiency, if these skills can be maintained overtime, and what impact team performance has on patient outcomes. In a time where PICU staff turnover is high nationally, identifying the percentage of staff that should be trained to effectively cross pollinate these teamwork concepts into everyday practice is important. In addition, simulated-based team training can be used as a platform to analyze common trends in behaviors of native teams. Future research involving quantitative evaluation by a human factors specialist can provide healthcare systems with vital information that can identify latent safety threats and inform future trainings.

Conclusions

Simulation-based team training is effective in teaching team performance concepts to multidisciplinary teams in the pediatric ICU in the simulated environment. These teamwork concepts can be applied to the management of DMCs as well as cardiopulmonary arrest. SBTT can be used to provide insight into the functioning of native teams and can inform future training programs.

Note

This study was performed in the Division of Pediatric Critical Care at Children's Healthcare of Atlanta, Emory University. There is no conflict of interest, financial or otherwise, to be disclosed by any of the above authors. The paper falls under nonhuman subject category and was approved by the Children's Healthcare of Atlanta Institutional Review Board.

Dr. Colman performed background research, designed and conceptualized the study, collected data, prepared the article, and approved the final version as submitted. She had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Janet Figueroa and Courtney McCracken assisted in the study methodology, performed the initial statistical analyses, developed the figures and tables, reviewed and revised the article, and have approved the article as submitted. Dr. Hebbar conceptualized and designed the study, collected data, directed analysis reviewed and revised the article, and approved the article as submitted.

Conflict of Interest

None declared.

References

1 Reis AG, Nadkarni V, Perondi MB, Grisi S, Berg RA. A prospective investigation into the epidemiology of in-hospital pediatric cardiopulmonary resuscitation using the international Utstein reporting style. Pediatrics 2002;109(02):200–209

2 Meert KL, Donaldson A, Nadkarni V, et al; Pediatric Emergency Care Applied Research Network. Multicenter cohort study of in-hospital pediatric cardiac arrest. Pediatr Crit Care Med 2009;10 (05):544–553

3 Catchpole K, Mishra A, Handa A, McCulloch P. Teamwork and error in the operating room: analysis of skills and roles. Ann Surg 2008; 247(04):699–706

4 Dietz AS, Pronovost PJ, Mendez-Tellez PA, et al. A systematic review of teamwork in the intensive care unit: what do we know about teamwork, team tasks, and improvement strategies? J Crit Care 2014;29(06):908–914

5 Baker DP, Amodeo AM, Krokos KJ, Slonim A, Herrera H. Assessing teamwork attitudes in healthcare: development of the TeamSTEPPS teamwork attitudes questionnaire. Qual Saf Health Care 2010;19(06):e49

6 Cheng A, Donoghue A, Gilfoyle E, Eppich W. Simulation-based crisis resource management training for pediatric critical care medicine: a review for instructors. Pediatr Crit Care Med 2012;13 (02):197–203

7 Weinstock P, Halamek LP. Teamwork during resuscitation. Pediatr Clin North Am 2008;55(04):1011–1024, xi–xii xi–xii

8 Baker DP, Salas E, King H, Battles J, Barach P. The role of teamwork in the professional education of physicians: current status and assessment recommendations. Jt Comm J Qual Patient Saf 2005; 31(04):185–202

9 Kennedy TJ, Regehr G, Baker GR, Lingard LA. Progressive independence in clinical training: a tradition worth defending? Acad Med 2005;80(10, Suppl):S106–S111

10 Dugan MC, McCracken CE, Hebbar KB. Does simulation improve recognition and management of pediatric septic shock, and if one simulation is good, is more simulation better? Pediatr Crit Care Med 2016;17(07):605–614

11 Adler MD, Overly FL, Nadkarni VM, et al; International Network for Simulation-Based Pediatric Innovation, Research and Education (INSPIRE) CPR Investigators. An approach to confederate training within the context of simulation-based research. Simul Healthc 2016;11(05):357–362

12 Nadkarni LD, Roskind CG, Auerbach MA, Calhoun AW, Adler MD, Kessler DO. The development and validation of a concise instrument for formative assessment of team leader performance during simulated pediatric resuscitations. Simul Healthc 2018; 13(02):77–82

13 Guise JM, Deering SH, Kanki BG, et al. Validation of a tool to measure and promote clinical teamwork. Simul Healthc 2008;3 (04):217–223

14 Volk MS, Ward J, Irias N, Navedo A, Pollart J, Weinstock PH. Using medical simulation to teach crisis resource management and decision-making skills to otolaryngology housestaff. Otolaryngol Head Neck Surg 2011;145(01):35–42

15 Gettman MT, Pereira CW, Lipsky K, et al. Use of high fidelity operating room simulation to assess and teach communication, teamwork and laparoscopic skills: initial experience. J Urol 2009; 181(03):1289–1296

16 Morgan L, Hadi M, Pickering S, et al. The effect of teamwork training on team performance and clinical outcome in elective orthopaedic surgery: a controlled interrupted time series study. BMJ Open 2015;5(04):e006216

17 Morey JC, Simon R, Jay GD, et al. Error reduction and performance improvement in the emergency department through formal teamwork training: evaluation results of the MedTeams project. Health Serv Res 2002;37(06):1553–1581

18 Gilfoyle E, Koot DA, Annear JC, et al; Teams4Kids Investigators and the Canadian Critical Care Trials Group. Improved clinical performance and teamwork of pediatric interprofessional resuscitation teams with a simulation-based educational intervention. Pediatr Crit Care Med 2017;18(02):e62–e69